TABLE 8.—*Computations of total cotton production by the application of the constants of the equation of the straight line of best fit, shown in Table 7, to the weather data and ginning reports for November. Cotton data given to nearest 1,000 running bales, as reported by the Bureau of the Census, Department of Commerce.*

Year.	1	2	3	4	5	6	7
1905	2,232	53.2	4,195	6,458	10,653	10,495	+1.5
1906	3,122	57.1	5,468	6,906	12,374	12,983	−4.7
1907	2,214	44.3	4,998	6,129	11,127	11,058	+0.6
1908	2,817	57.5	4,899	8,192	13,091	13,086	±0.0
1909	1,859	60.9	3,053	7,018	10,071	10,073	±0.0
1910	2,794	62.6	4,463	7,346	11,809	11,568	+2.1
1911	2,846	46.8	6,081	9,971	16,052	15,553	+3.2
1912	2,986	66.0	4,524	8,869	13,393	13,489	−0.7
1913	3,258	58.3	5,588	8,830	14,418	13,983	+3.1
1914	3,246	53.7	6,045	9,827	15,872	15,906	+0.2
1915	2,325	63.0	3,690	7,379	11,069	11,068	±0.0
1916	1,728	62.2	2,778	8,624	11,402	11,364	+0.3
1917	2,529	64.3	3,933	7,185	11,118	11,248	−1.2
1918	1,794	48.5	3,699	7,777	11,474	11,906	−3.6
1919	2,539	52.8	4,809	6,305	11,114	11,326	−1.9
Average							1.5

Column 1.—Amount of cotton ginned during November.
Column 2.—Computed percentage of the cotton remaining to be ginned on November 1, that was ginned during November (computed from equations in Table 7, applied to weather data).
Column 3.—Computed amount remaining unginned on November 1 (column 1 divided by column 2).
Column 4.—Amount ginned prior to November 1.
Column 5.—Computed total crop (column 3, plus column 4).
Column 6.—Total crop, as reported by the Bureau of the Census, Department of Commerce.
Column 7.—Percentage of error in computed amount.
NOTE.—These computations can be made as soon as the ginning report for December 1 is available, while the actual totals are not available through the report of the Census Bureau until the latter part of the following March, or later.

FORECASTING THE CROPS FROM THE WEATHER.[1]

[Abstract of presidential address of R. H. Hooker, before Royal Meteorological Society.][2]

Mr. Hooker remarked that forecasts of the harvest fell into two main groups, viz, those which predicted the recurrence of good and bad crops in cycles, and those which computed the actual amount by which the yield was improved or damaged by the weather during or shortly before the growing period. He outlined the evolution of the methods of ascertaining relationships between the weather at different seasons of the year and the subsequent harvest. Originally writers such as Gilbert and Lawes could only examine the meteorological conditions in years of exceptional abundance or scarcity. A great advance was made when Sir Rawson Rawson and, later, Sir Napier Shaw, from the study of an entire sequence of crops and previous weather conditions, suggested formulæ from which the crop might be calculated, while still wider possibilities were opened by the methods of correlation. Mr. Hooker emphasized the necessity of taking the past weather into account in predicting the harvest, as it was abundantly clear, from comparison with actual forecasts in India and elsewhere, that the weather was responsible for developments in the plant which were not visible to an observer surveying the young crops in the fields; and, although much work still remained to be done, the time was ripe for using statistics to confirm or modify the results of direct observation of the growing plants.

[1] *Quar. Jour. Roy. Met'l. Soc.*, Apr., 1921, 47:75–99.
[2] Reprinted from *Nature* (London), Jan. 27, 1921, p. 714.

BIOCLIMATIC ZONES DETERMINED BY METEOROLOGICAL DATA.[1]

By ANDREW D. HOPKINS.

[U. S. Department of Agriculture, Washington, D. C., Apr., 1921.]

In a comprehensive study of the relation of the Bioclimatic Law to the natural and artificial distribution of terrestrial plants and animals of the world the writer has developed a system of bioclimatic zones on the theory that a definite relation prevails between the range and limits of similar or equal zones of life and climate and the unit constants of *time*, *distance*, and *the thermal mean* of this law.

While the study of this relation and the development of systems of tables of constants, charts, etc., is yet in the preliminary stage, the fundamental idea of applying the law to the study of life zones, as suggested in SUPPLEMENT 9 of the MONTHLY WEATHER REVIEW, 1918, p. 38, has been developed, and tested, to a sufficient extent to warrant the presentation of the result relating to a *thermal mean principle* of forecasting the bioclimatic zones that are represented by the meteorological stations of the world.

The term *Bioclimatic Zone* has been adopted to include the elements of both life and climate that characterize the zonal complex of responses, primarily to the solar factor, and secondarily to those represented by the variable features of the earth's surface.

The classification of zones to meet the requirements of universal application is briefly as follows:

The major zones are the frigid, temperate, and tropical, designated by Roman numerals I, II, and III. These majors are divided into minor frigid, minor temperate, and minor tropical, which are designated by Arabic numerals.

I. The Major Frigid Zone is Arctic, Antarctic, and Alpine, with Minor Frigid 1, 2, 3, and 4 from the poles and from higher to lower altitudes.

II. The Major Temperate Zone is south and north of and below Major Frigid I, with Minor Temperate 1, 2, 3, 4, 5, 6, and 7, south and north of and below Minor Frigid 4.

III. The Major Tropical Zone is south and north of and below Major Temperate II, with Minor Tropical 1, 2, 3, 4, south and north of and below Minor Temperate 7.

This system of designations and classification of the zones is with the idea of adopting a terminology that is applicable to any continental or insular area of both hemispheres, instead of the usual names based on geographical features, political divisions, regions, etc., of one country or continent.

The major zones of this classification are not different from those which have long been recognized, except that their poleward and equatorward limits *do not follow the parallels of latitude even at sea level.*

The minor zones correspond in general to the minor temperate zones proposed by Dr. Merriam for North America, but his Hudsonian and Canadian do not apply to other continents and Austral and Sonoran for North America do not apply in the same way to South America or Africa.

CHARACTERIZATION OF BIOCLIMATIC ZONES.

Each major and minor zone is characterized by some peculiar element or group of elements of life and climate by which it may be recognized anywhere on the face of the earth where it is represented by greater or less land areas.

The index or characterization elements of the minor zones and their subdivisions into sections are many and varied. Some of the principal ones are the thermal

[1] Presented before the American Meteorological Society, Washington, D. C., Apr. 20, 1921.

index, life type and ecological index, the isophane and altitude index including timberline, and the phenological index.

Among these features of characterization the thermal mean is fundamental as a response to the solar factor; therefore, no matter to what extent the physical aspects as to climate, weather, topography, soil, etc., may vary, the normal range of the characterizing temperature, between the poleward and equatorward or lower and upper altitude limits of a given major or minor zone, will, in general, remain the same.

Therefore, it is to temperature that we must look for the most reliable guide to the preliminary interpretation of the distribution and range of the zones, so far as they are represented by the geographical position of permanent meterological stations from which records are available for a sufficient period of years to represent the normal thermal response to the prevailing influences.

The essential basis for the application of the *thermal mean principle* of identifying bioclimatic zones is a table of sea level thermal constants, for the sea level isophanes of the continents of the northern and southern hemispheres, computed from the records at an intercontinental base. After some months of study of the recorded means sea level isotherms, etc., from different parts of the world, a preliminary table was prepared with Parkersburg, W. Va., as the intercontinental base station; the normal annual July and January means for 15½ years as the base data; the thermal unit constant or gradient of 1° F. to each one degree isophane as the unit of computation the principle of modified thermal influence on life activities with higher and lower latitudes and higher altitudes[2] as the correcting element and the numerical designations of bioclimatic zones corresponding in isophanal range with a corresponding range in the thermal mean for each minor zone and its lower, middle and upper section. This table enables us to indicate the zone represented by the geographical position of any meteorological station in the world, by simply comparing its recorded means with the corresponding thermal constants of the table.

The recorded means at over 600 stations given in Bulletin Q of the Weather Bureau were utilized to test the practicability of the thermal method of zonal predictions, with the result that in nearly every case the recorded mean gave the correct zone as represented by the later life zone maps of the Biological Survey. More recently the records of many hundreds of stations, principally in Eurasia have been compared with the table of constants with most encouraging results.

The thermal principle is based on the theory that—

1. The temperature below that favorable for life activities during the coldest month, January, north, and July south of the Tropical zone contributes to the poleward or higher altitude limit of the species which characterize a warmer zone.

2. The temperature above that favorable for the beginning of life activities during the hottest month, July, north, and January, south of the Tropical zone, contributes to the equatorward or lower altitude limit of the species which characterize a colder zone.

In the application of this principle the following rules are to be followed:

1. When the annual July and January means give the same zone and approximately the same section of the zone, it represents what may be termed a normal or a balanced climate as related to zonal characterization, so that either the annual July or January or the average of the July and January means will indicate the zone and position within the zone represented by the station.

2. When there is a more or less wide variation in the zones indicated by the July and January means, as (*a*) the July represents a more poleward or Alpine and the January a more equatorward zone, either the annual, or the average of the July and January means will serve as the best index, or (*b*) when the July represents a more equatorward and the January a more poleward zone, the July mean will be the best index.

Thus, for a region like the western coasts of North America and western Europe where the winters are abnormally warm and the summers abnormally cool, Rule *a* applies, while in north central North America and Eurasia, where the winters are abnormally cold, and the summers abnormally warm, Rule *b* applies, and in eastern North America and Eurasia where the temperature relations are more equally balanced, as related to the zones, Rule 1 applies.

For examples, *under Rule 1*, for Millsboro, Del., on the eastern coast of North America, the annual July or January gives minor zones $-4+5$,[3] and for Tokyo, Japan, on the east coast of Eurasia, on about the same isophane, the annual and July means give minor $\odot 5$ and the January -5, so that any one of the means in both of these examples indicates approximately the correct zonal position.

Under Rule 2a, for Tatoosh Island, Washington, on the west coast of North America, and about the same isophane as Example 1, the annual and the average of July and January means give minor -3, the July minor -1, and the January minor $\odot 6$, and for Florö, Norway, on the western coast of Eurasia, and on about the same isophane, the annual and the average means give minor $-2+3$, while the July mean gives $-1+2$, and the January $+5$. In both of these examples the annual mean indicates the correct zonal position.

Under Rule 2b, for Willow City, N. Dak., in central North America, the July mean gives $-2+3$, the annual $-1+2$, and the January and the average of the July and January means give $\odot 1$, and for Slatoust, Russia, in central Eurasia, the July gives temperate $\odot 2$, the annual temperate $+1$, the January, *frigid* $+\odot 4$ and the average July and January gives temperate $+1$.

In both of these examples the July mean indicates the correct zone.

It must be remembered that the thermal mean is only one of many methods of indentifying the zone represented by a geographical position and therefore is not to take the place of, but to supplement, the other methods. Its value, however, in making preliminary predictions when no other method is available is clearly indicated in the fact that, for a thousand or more stations, the predictions by this method appear to agree closely with the facts and in many cases do agree as close as they can be determined by any method short of a detailed survey.

Therefore, when we learn to recognize and properly interpret this, and the various other guides to the major and minor features of the bioclimatic zones, it will be an easy matter to not only determine the zones represented by a given region and section of the country but what section or minor element of a zone is represented by a certain place on a given farm. Then we will realize all, and far more, than Dr. Merriam and others have claimed for the life zones, as guides to the development of human welfare in food, health and prosperity.

[2] Hopkins, A. D.: Mo. WEATHER REV., Apr., 1920. 48; 214-215.

[3] $-$ equals lower; $+$, upper; $-\odot$, lower middle; $+\odot$, upper middle; and $\odot$, middle sections of a minor zone.